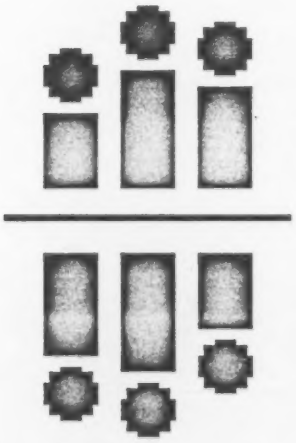
Policy Study Series

Center for Information Technology and Society

EDUCATIONAL TECHNOLOGY: INFORMATION NETWORKS, MARKETS AND INNOVATION

PART V

REFERENCE MATERIALS:
A Comprehensive Bibliography
on
Educational Technology, Innovation, Adoption and Policy
(and Appendices)



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Part I — *General Framework on Markets, Nonprofits, Patrons, and Policy*

Part II — *Information Networks: The Diffusion of Innovation and Highlights of Discussions with Eighteen Networks of Teachers, Administrators, State Coordinators and Other Information Providers*

Part III — *Survey of Ten Educational Software Firms: A Study of the Economics of the Market and the Process of Technological Innovation*

Part IV — *A Survey of Four Firms Involved in Both Educational Software and Business Products*

Part V — *Reference Materials: A Comprehensive Bibliography on Educational Technology, Innovation, Adoption, and Policy* and Appendices

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EDUCATIONAL TECHNOLOGY: INFORMATION NETWORKS, MARKETS AND INNOVATION

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PERSPECTIVE ON EDUCATIONAL TECHNOLOGIES

Presented at the OTA Workshop on Cost Effectiveness
of Educational Technology
December 9, 1986

As some brief background, I was part of a think tank-like group for nearly ten years at MIT called the Center for Policy Alternatives. Some of the perspective I will share here comes from my experiences in understanding the nature of technological innovation and the relation of technological change to society. I am a co-author of the book *Technological Innovation for a Dynamic Economy* published by Pergamon Press. Earlier this year I formed the Center for Information Technology and Society to continue this work in the areas of information and communication technologies.

What have We Learned

It is very important that we back up or away from our current era in thinking about educational technologies. Within the current industrial paradigm, we may very well be past a stage of progressive educational growth and development. In the language of the analysis of technological innovation, the current focus is on *process innovation* rather than *product innovation*. We are not asking what new curriculum we should teach but how can we teach what we've taught more efficiently.

But let me suggest that we are behaving very much like any mature, rigid industry such as for automobiles or steel. First, there may be distinctly different technological ways of making steel (as we found from the Japanese) and second, we may want less steel and something else for society.

Education often mirrors society. In the last decade many politicians and educators have agreed that education in our society is something that should be put into service for increasing the economic strength of the nation. Indeed, the balance of trade

suggests that in the battle of industrial competition, we have grown soft and have lost ground.

Within this context, educational technology is viewed as a means to an end rather than a new form of social growth. We are preoccupied by counting incremental improvements in traditional skills as evidence of education.

But let me remind you why many of us came to this New Land. Charles Sanford in *Quest for Paridise* characterized the American people as a people that were dissatisfied with European status quo and convinced that something better could be achieved for the good of mankind.

In that quest, we discovered industrial might and the standard of living that that might could bring. But we have gotten stuck with industrial might as if it were THE QUEST.

But the quest was and continues to be social growth in ways that betters the condition of mankind. A dream of the 60's was that we were just around the corner from fulfilling this quest in terms of universal love and freedom. The sense of the 60's *was* mistaken, not in its scope and direction, but in its timing. The economic realities of world competition became more important.

And now, there is something terribly hollow about our current age. We are aware of a myriad of skeletons in the closet – as evidenced by high divorce rates, considerable sales of tranquillizers, child abuse, and a constant drama of violent and disturbing messages in our news reporting and in our television programming. Yet we occupy ourselves with trying to improve education by increasing math SAT scores, etc. and educational technology is evaluated in that context and that alone.

But the technologies that we have today and tomorrow are some of the most promising means for the social change that John Dewey envisioned for American society and culture. John Dewey suggested in *Characters and Events* (1929) that America was 1) in need of developing its own culture and 2) would be more likely to succeed by looking forward and creating a culture that genuinely acknowledged man's new industrial might, his newly acquired knowledge in science, as well as the ideals that Americans cherished. Dewey despaired of turning to earlier classicism and dogma and instead looked forward – "To transmute a society built on an industry which is not yet humanized into society which wields its knowledge and its industrial power in behalf of a democratic culture requires the courage of an inspired imagination."

But what makes the evolving technology so promising when we have witnessed how inhumane some technology can be such as nuclear armaments, assembly line work, and the measurment of man's success by a count of his material goods (all products of technology).

The difference lies in the inherent ability of information and communication technologies to amplify and leverage the more humanistic aspects of society and culture. This is because these characteristics of society are embodied in language and thought, and the new technologies are enhancing language and thought. With computer teleconferencing we are witnessing the establishment of new networks that tie people into common bonds. Computer programs are increasingly embodying the wisdom of what a good society is comprised. And the more these programs demonstrate to our children and to us how virtues of a society function to make a good society,. the more compelling will be their existence. Horace Mann envisioned that public education was the one place where we could teach the common denominator of

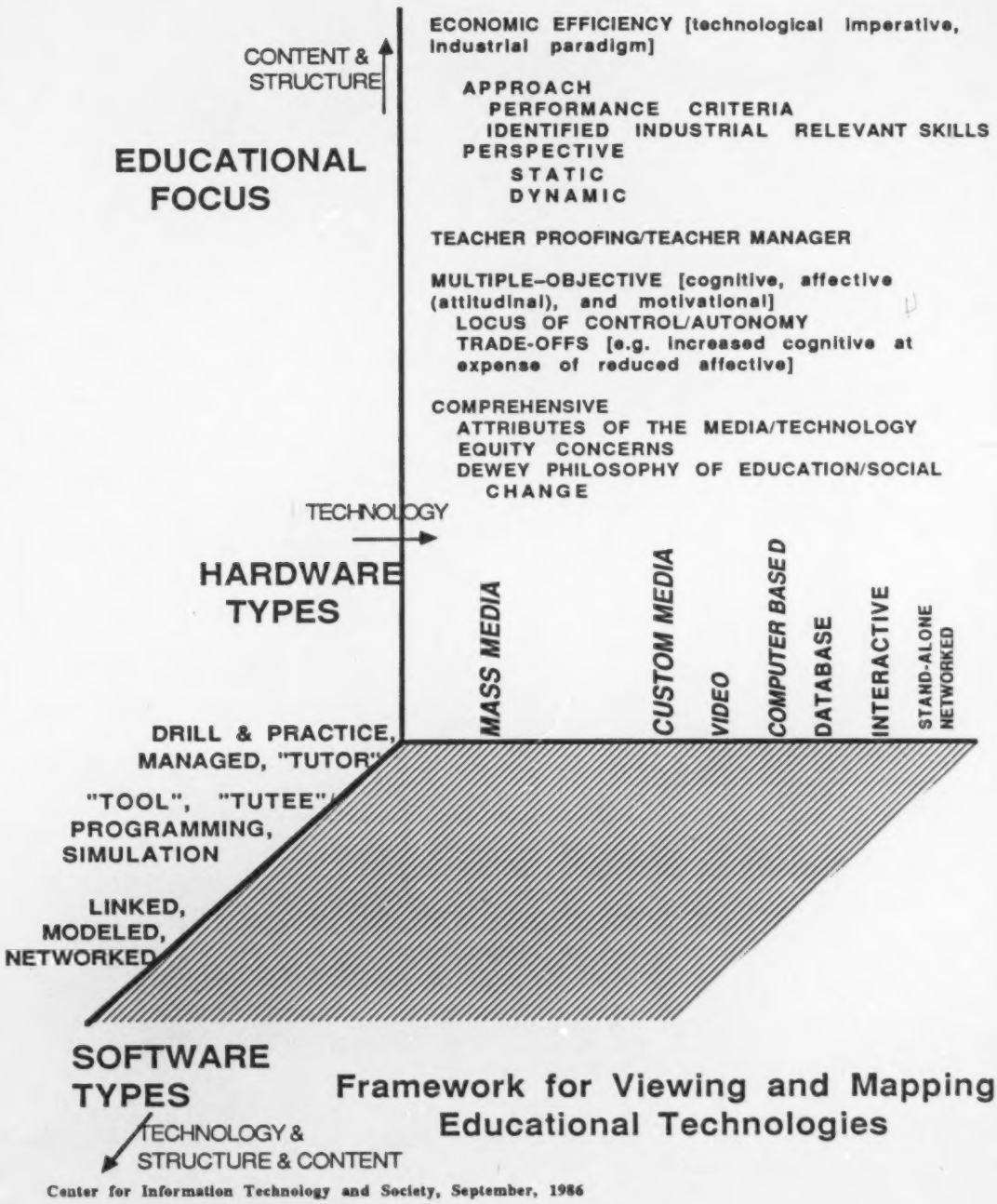
what all religions and cultures agreed was good. Taking this a further step, by embodying in our computer programs and networks and models, the same vision, the same common denominator, we build a legacy and invest in societal tools that with refinement will serve countless generations in the future.

Let us turn to a view and map for educational technologies. We are making choices each month and each year about what educational technologies promote. And when we do nothing or "let the market" determine what educational technologies will survive, this too is a choice we have made. It is important to have a framework in which to view these choices.

A single page map helps to condense the educational technology world into a single explanatory object. It has an integrating effect that places disparate pieces together as a whole. A single page can easily hold at most three components or dimensions of a situation (the x, y, and z axis') and I have chosen for those dimensions: hardware types, software types, and educational focus. The hardware types and software types represent a technological dimension and the educational focus and software types, again, represent a content or structural dimension of education. It is important to see that software types embody both technology and content.

Guidelines for Research and Implementation

In terms of the Framework for Viewing and Mapping Educational Technologies, it is important to keep clear what choices we are making for what types of implementations of educational technology. Should we allocate resources to developments along only those that are measurable which will mainly be restricted to identified industrially relevant skills or should we allocate resources toward more comprehensive aspects of education? This is a political question that to some sizable extent will be answered by the political process. However, to leave our most valuable, long-term resource to short-run political processes is precarious. What is needed is educational leadership



Framework for Viewing and Mapping Educational Technologies

Center for Information Technology and Society, September, 1986

that both recognizes the wide range of educational objectives and the potential for educational technology. Perhaps the leadership will be in the form of another John Dewey, or perhaps we can fashion a board or council with this charge. The monetary reserve board and the U.S. supreme court are two successful examples of institutions that have buffered policy from short-term political interests.

One bill before Congress by Nunn and Lautenberg has called for the establishment of an *Information Age Commission* (S. 786, 99th Congress, 1st Session) and another bill by George Brown calls for the establishment of an *Institute for Information Policy and Research* (H.R. 744, 99th Congresss, 1st Session). Perhaps one of these bills is a vehicle to introduce the idea of an Educational Technology Policy Board.

The fundamental problem, however, is understanding how important educational technologies are to the country. One solution to this is along the lines of the Shavelson study described in the paper presented by Prof. Stern at this workshop. Stern recommends "shedding light on the process of innovation, if possible including a look at spontaneous grass-roots experimentation as well as large-scale, formal R & D projects." Let me add the importance of distinguishing the various projects along the dimensions of the educational technology framework. This serves two purposes: it helps us to understand each cell of the framework by examining projects that belong to each cell, and it reminds us of what our current emphasis is with respect to the range of possibilities and alternatives.

Appendix B

Schools of Approaches in Identifying Innovation

This piece is excerpted from
Identifying and Assessing Discrete Technological Innovations: An Approach to Output Indicators [Priest, 1980]

This section discusses approaches to identifying and measuring innovations as evidenced by an extensive literature search. While the main purpose of the paper is to concentrate on the measurement of discrete innovations, it is useful to explore other approaches to put this particular method in perspective.

Productivity

The bulk of the literature relating to technological innovations reflects a general concern for increasing productivity in the realm of economic enterprise. For the most part, the nature of the innovations employed to increase productivity is left unspecified. The emphasis is on measuring productivity as the first step to improving productivity.

The literature is reasonable diverse. Many pieces deal with improving productivity in, for example, the paper industry, in navy ship design, in Japanese industry in general, and in plastic pipe production. The literature also reports productivity concerns in the public sector. There are several pieces on the formal measurement of productivity in Candadian government. Other pieces are concerned with health care productivity, including the productivity of doctors and hospitals. Several other pieces are concerned with measuring productivity of service personnel such as

salespersons and clerks.

The orientation of this literature is to provide input-output types of productivity measures to administrators and managers, whose tasks are to bring about the innovations required to improve productivity.

Production Function

Productivity literature has taken two paths since Kendrick structured the concepts of labor productivity and total factor productivity in the 1950's. The productivity literature mentioned in the previous section has emphasized communicating the basic concepts of productivity to the practising audience, while production function literature has gone in the direction of developing a theoretical structure for modelling the economic behavior of a firm or industry as factor prices, inputs, outputs and technologies are changed. Murray Brown [Brown, 1968] presents a useful, though now somewhat dated account, of the measurement of technological change in the production function literature.

Solow [Solow, 1957] originally conceived the method of accounting for changes in output due to changes in input factors and a residual that included technological changer for the economy or parts of the economy as a whole. Since that time, the literature has been filled with attempts to measure technological change in various industries and in the entire economy, as well as with critiques of the validity of the basic method. Jorgensen and Griliches [1972] argue that on the whole the residual is due to errors in methods and biases in measurement. The basic problem is in using a measure that attempts to measure technological change (or innovation) by subtracting away all other factors. The sense of the

literature is that this can be useful on a case-study basis where factors are well measured, but is seriously flawed at the aggregate level.

Input Measures

Input measures include measures of R&D activity, patent activity, and numbers and levels of technical personel. The general assumption is that higher levels of these inputs are correlated with greater production of innovations. In general this assumption appears to hold, though the literature is filled with qualifications and critiques of these approaches. The Science Indicators group of NSF presents a selection of these measures [NSF, 1978] and bases some of its conclusions on a series of papers performed for SI.

As a general means of identifying and quantifying innovative activity, input measures appear to be the best available information to-date. Pavitt and Soete have explored the relationship between R&D and patent activity. They suggest that R&D expenditure might be a better proxy for innovative activity in large firms and patenting activity a better proxy in small firms [NSF, 1978].

These measures serve as adequate proxy measures, of course, only to the extent that input measures and outputs of innovations are correlated. Areas that are highly innovative, but do not fall into the "mold" of requiring high levels of R&D or patenting will be completely missed by this approach. This has certainly been the case, say, in using patent counts to detect advances in computer technology, because much of the innovation has shifted to the software areas, where unless the Supreme Court rules otherwise, software cannot be patented.

Multivariate Measures

Another school of measurement of technological change and innovation uses a multiattribute approach. In this approach, performance and physical characteristic features of a technology are measured. Changes in a composite of these measures provide a measure of technological innovation. A pioneering piece of work in this areas was performed by Alexander and Nelson in measuring technological change in aircraft turbine engines [1973]. This piece, however, was not without many of the statistical errors that can be commited in such an endeavor, as pointed out by Klitgaard [1974]. Further development of a "generalized distance measure of technology" has been published by Devendra Sahal [1976].

The types of physical quantities that these studies focus on are performance and physical characteristics such as weight, horsepower, speed, cycles-per-second. A "factor analytic" approach is used to discern the similarities and differences betweeen items. Discriminant analysis and clustering techniques are appropriate analysis tools. The major difficulty in this approach is in combining multiple measures associated with a single device. If speed and weight are two separate attributes, it is not clear how they should be interweighted and combined as a single measure. Furthermore, it is not clear how a measure of technological change associated with one technology can be compared with that of another.

At each step, relative weights must be assigned and there is no practical theoretical basis for doing so. Of course, this difficulty is

characteristic of any other approach and is only magnified using this approach. Eventually one wishes to know the relative value of one innovation to another. For example, in the case of patent data, not only is the relationship with innovation tenuous but also counts of patents without regard to "importance" can provide a false sense of the actual level of innovation in a valuative sense.

Multivariate approaches are most relevant to discerning changes in a particular technology over time. As Alexander has noted [Personal Communication, 1980], it was difficult to say what the discrete changes were to the aircraft turbine engine, but after a few years, the performance parameters indicated that considerable technological innovation had occurred.

Discrete Measures

Discrete measures of innovation are th subject of the next section of this paper. Discrete measures differe from the other approaches in that each innovation must be specifically identified. They cannot be hidden in the midst of a "gradual" technological change that is revealed through changes in productivity or other aggregate measures.

[Extracting from Chapter 3, on discrete measures]

In identifying technological innovations to make discrete counts one can take advantage of the fact that when change occurs it is necessary to differentiate one part, entity, etc. from another by changing its name [a name change occurs either when a particular function is performed via an innovation or when a new function is being performed.] Sometimes the change is so pronounced that the entire word for the item is changed, such

as from carriage to automobile. At other times the change is denoted by a change in the adjectives that modify the word, such as from diesel engine to turbocharged diesel engine.

Technological innovations can be identified as the newly named commodities at a given level of resolution. The rate of technological innovation can be measured by counting the changes in the number of names on a comprehensive list of commodities identified at a given level of resolution. This is our fundamental rule for using discrete counts to measure technological innovations.

[Excerpting further from Ch. 5 on the application of the discrete approach]

Telecommunications

Judging from the general literature and the growth of companies, telecommunications is an area abounding with innovations. It is also an area in which commodity names change almost overnight. Text editors have become word processors; management information systems have become distributed management information systems; and terminals have become both dumb terminals and smart terminals.

The choice of the appropriate level of resolution is different for input and output devices than it is for networks. Input and output devices are primarily sensory and manipulative extensions of the human body. Thus an appropriate level of resolution regarding input and output devices would be at a level that could discern notable differences in the ability for persons to receive and transmit information. With regard to say a CRT terminal, phrases like "character," "line insert" and "delete" are important distinctions because they affect the speed at which the displayed

information can be changed for a fixed level of data transfer capacity to the terminal. (Without these internal screen functions, the screen of a CRT needs to be completely rewritten if a character is changed at the beginning of the text.) Thus, to determine whether innovation has occurred for input and output devices one would count the changes in the commodity lists at a level that was sensitive to these humanly detectable changes.

A ready source for such an identification process is the series of publications by Datapro. This company publishes continually updated specifications regarding all commonly available input and output devices.

The choice of an appropriate level of resolution for the network [— the maze of computers, storage devices, telecommunications software, application software, and transmission lines], i.e., for interconnecting devices, is a far more challenging problem. A network not only connects devices but also connects devices to stored information. To properly define the domain of a network for purposes of innovation one should include increasing levels of symbiosis between devices and stored data; the complexity of which is probably only limited to the extent of our society's transactional capacity [see Priest, 1972].

The appropriate level of resolution for the network is the transaction level. Lists of types of transactions could be constructed, and changes in those lists of transactions would be indicative of technological innovation within the network. Broad categories of transactions such as business, interpersonal, educational, etc. could be used, with subcategories capable of indicating signficant shifts within these areas.

The basis for these lists could come from materials published by

schools of communications, mass communication, and other transaction-oriented disciplines such as business administration.

Appendix C

CENTER FOR INFORMATION TECHNOLOGY AND SOCIETY

Project on Educational Technology, Information Networks and Markets

FIRM SURVEY QUESTIONNAIRE

JUNE 19, 1987

FIRM CODE #:_____

I. Background

(Could you tell me about your—)

I-1. Sales levels

I-2. Number and type of products

1-3. Ownership and Organization of the Firm

Marketing Channels

I-4. Use of Representatives

I-5. Direct Sales

I-6. Wholesalers, retailers

I-7. Levels of R&D funding

Management

I-8. Style of Leadership

I-9. Flexibility among staff

II. Products/Innovation

(Could you tell me about your —)

II-1. Relationship of software to other product lines (type and %'s)
(Degree of horizontal integration)

II-2. Novelty of Innovations (degree and percentages)

Areas of innovative activity by product and process (percentages)

- II-3. R&D
- II-4. licenses
- II-5. production
- II-6. sales preparation and marketing

Sources of Innovations (the innovative stimuli)

Internal

- II-7. R & D
(Especially "technology push")
- II-8. From production groups
- II-9. Marketing, product-image
(Especially "market pull")
- II-10. "suggestion box", etc.

- II-11. the firm's management

- II-12. other (please specify)

External

- II-13. suppliers

- II-14. customers

- II-15. competitors

- II-16. federal R&D, federal programs

- II-17. affiliated enterprises (e.g. joint ventures)

- II-18. exhibitions

- II-19. trade literature, associations, conventions, etc.

- II-20. acquisition and licensing

- II-21. other (please specify)

Innovation goals

- II-22. creation of successor-products to replace any to-be-discontinued products

- II-23 rounding out of product mix

- II-24. restructuring of production program (organizational changes)

- II-25. changing of the number of production stages which firm handles (make/buy)

- reduction of production costs via
  - o II-26. proportional reduction of wage costs
  - o II-27. decrease in input costs
  - o II-28. decrease in lost time
- II-29. interest in being a "product leader"
- II-30. other (please specify)

Innovation Barriers

- II-31. How do you see the conditions of the market in general (the economy) affecting your business?
  Degree of Awareness _____ | Degree of Concern _____
- II-32. Generally, how profitable is educational software compared to other software business and businesses in general?
  Degree of Awareness _____ | Degree of Concern _____
- II-33. Are you able to raise capital as you need it?
  Degree of Awareness _____ | Degree of Concern _____
- II-34. Are you able to get finance credit as you need it?
  Degree of Awareness _____ | Degree of Concern _____
- II-35. Do you find subsidies from local, state, or federal sources sufficient?
  Degree of Awareness _____ | Degree of Concern _____

- problems with acceptance

  - II-36. Is school curricula any problem with acceptance of your products?
    Degree of Awareness _____ | Degree of Concern _____

  - II-37. Are teacher interests any problem with the acceptance of your products?
    Degree of Awareness _____ | Degree of Concern _____

  - II-38. Are student interests any problem with the acceptance of your products?
    Degree of Awareness _____ | Degree of Concern _____

- II-39. Do you have any insecurity about the long-range demand within existing and/or new markets (risk and uncertainty)
  Degree of Awareness _____ | Degree of Concern _____

- II-40. Do you have any personnel problems, personnel shortages in bringing products to market?
  Degree of Awareness _____ | Degree of Concern _____

- II-41. Is there any lack of innovation from suppliers? (e.g. software development tools, equipment, etc.)
  Degree of Awareness _____ | Degree of Concern _____

- Other forms of market failure
  - o II-42. appropriability (Do you find copyright protection protection sufficient?)
    Degree of Awareness _____ | Degree of Concern _____

o II-43. non-depletability (Do you find that older products are hard to replace with newer ones?)
Degree of Awareness _____ | Degree of Concern _____

[NOTE: MOVED THIS QUESTION OUT OF ORIGINAL ORDER]

o II-48. Intangibility (Are innovations that really help learning appreciated and purchases consequently possible?)
Degree of Awareness _____ | Degree of Concern _____

o II-44. externalities (To what extent do you see your purchasers able to incorporate in their funds the value of the learning to our general future prosperity and well-being?)
Degree of Awareness _____ | Degree of Concern _____

o II-45. Indivisibilities (Can the market support more "pieces", smaller chunks of software, etc.? E.g. the $5 package that performs a very limited function)
Degree of Awareness _____ | Degree of Concern _____

o II-46. Economies of scale and scope (Does a small firm feel disadvantaged to the larger firms in this business?)
Degree of Awareness _____ | Degree of Concern _____

o Uncertainty and risk [covered above]

o II-47. Information (How aware are teachers, administrators, and others about the usefullness and availability of your products? Are they able to judge them well?)

Degree of Awareness _____ | Degree of Concern _____

o II-49. Transactions Costs (What burden is there of having to deal with school boards at many levels for curricula changes?)

Degree of Awareness _____ | Degree of Concern _____

o II-50. Aggregate Overinvestment (To what extent are competing packages similar and duplicative?)

Degree of Awareness _____ | Degree of Concern _____

o II-51. Integenerational Legacy (To what extent do buyers see purchases as benefiting future generations?)

Degree of Awareness _____ | Degree of Concern _____

o II-52. Equity Concerns (To what extent has the company singled out disadvantaged populations for software development beyond that attracted by government subsidy?)

Degree of Awareness _____ | Degree of Concern _____

III-1. SUMMARY COMMENTS

Appendix to Survey

Preface to Discussions:

This is Dr. Curtiss Priest, Director of the Center for Information Technology and Society. I am conducting a study about educational software as part of a larger study by the U.S. Congress.

The general purpose of the study is to find out whether schools, administrators, and teachers are taking full advantage of new products and services. Our Center is a nonprofit group in Lexington MA that has a similar interest in seeing that the new technology is well received.

I have a number of questions I would like to ask you about your own firm's experiences. Let me first assure you that all responses will be on an anonymous basis and never will be attributed to your specific firm. In twenty years of performing such studies I have maintained a complete degree of integrity.

The sorts of questions I will be asking are typical of prior studies where we have investigated how firms innovate. If you have any question about anything I am asking please do not hesitate to ask.